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GB 2255831 A **US 5611311 A** **US 4995351 A**

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(54) Abstract Title
Determining the start of fuel injection or point of combustion in an internal combustion engine

(57) A method of determining the start of injection or the point of combustion in an internal combustion engine comprises the step of measuring combustion chamber pressure of an engine cylinder by means of a pressure sensor (14 to 17) and also measuring crankshaft angle (α). The measured course of combustion chamber pressure as a function of crankshaft angle is compared with a computed pressure course in a microprocessor (23) of a control device (19), wherein the computation takes place for a polytropic change in state. The start of injection or point of combustion can be ascertained from the difference between the measured pressure course and the computed pressure course.

Fig. 1

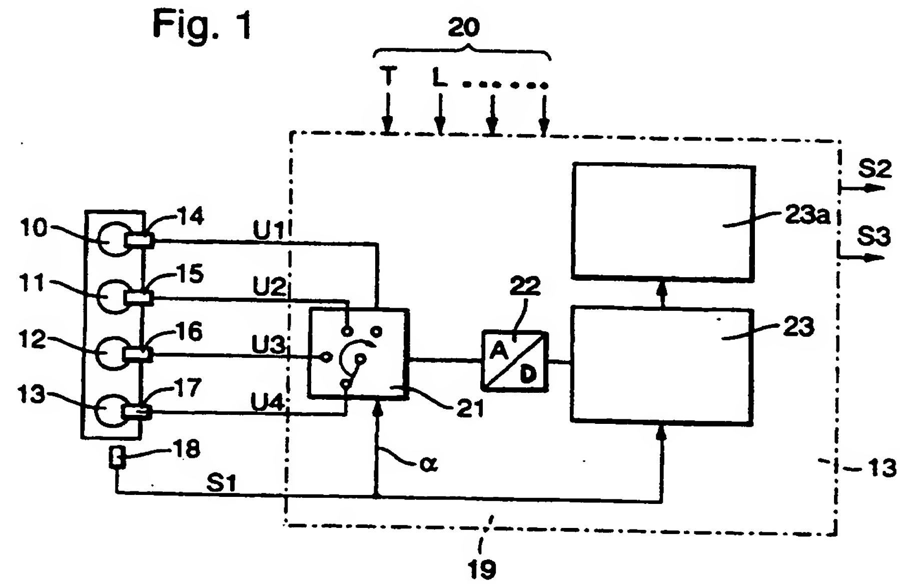

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Fig. 1

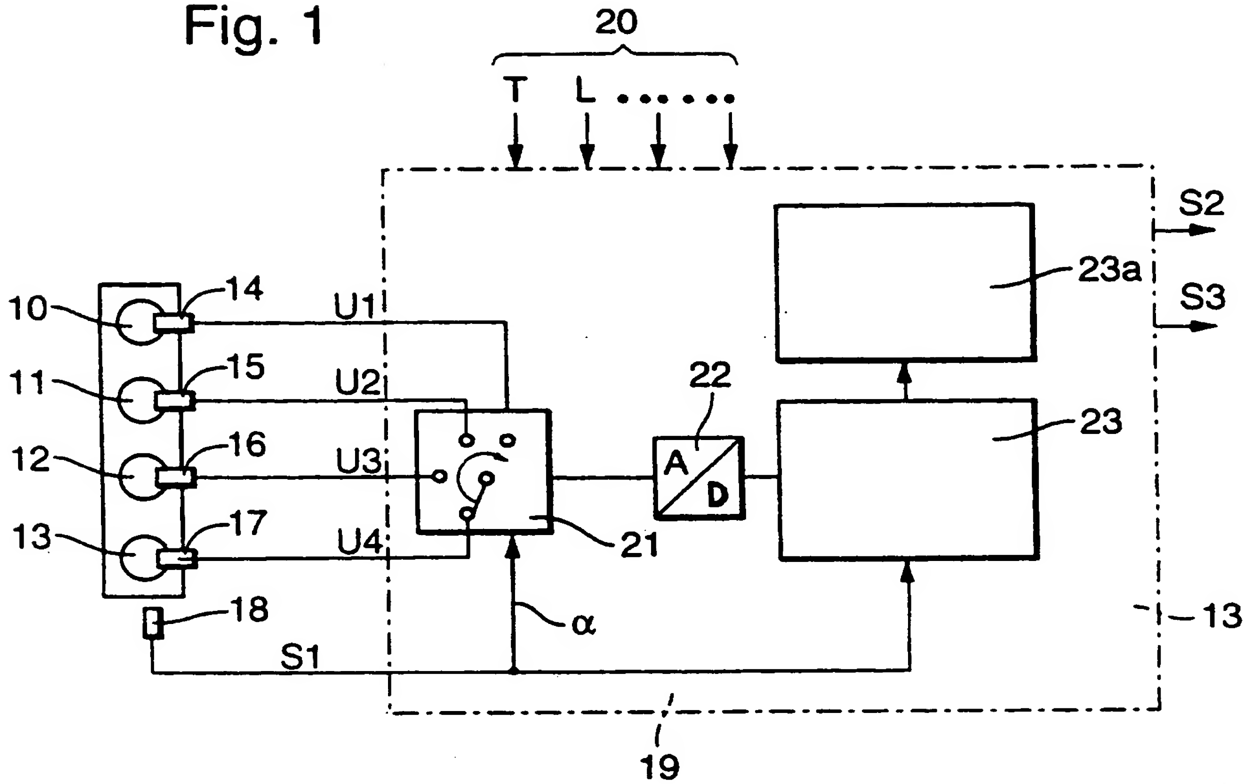
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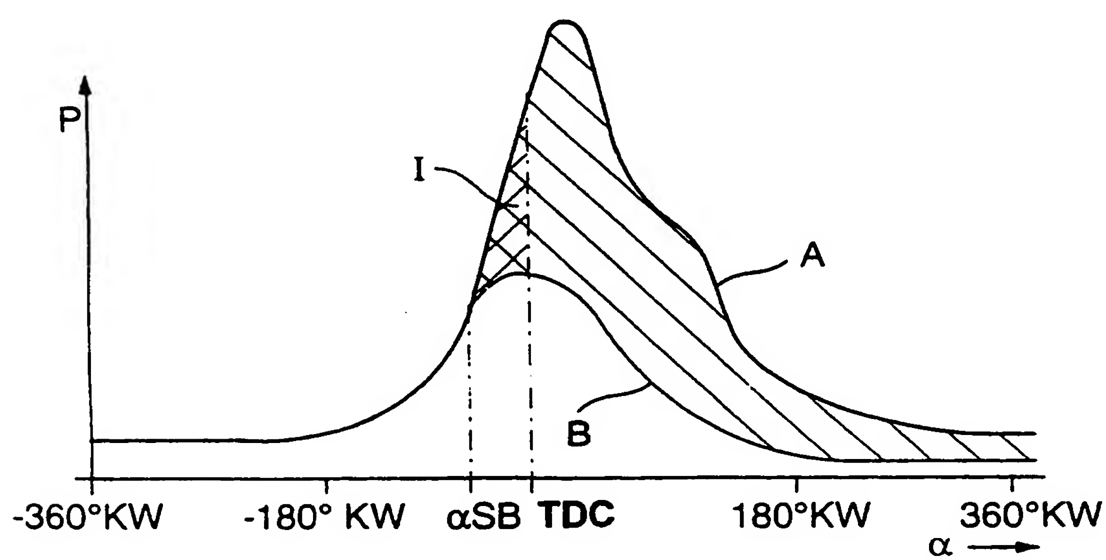
Fig. 2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DETERMINATION OF START OF INJECTION OR POINT OF COMBUSTION IN AN INTERNAL COMBUSTION ENGINE

The present invention relates to a method of and determining means for determining the start of injection or point of combustion in an internal combustion engine.

It is known to ascertain the course of the combustion chamber pressure in at least one cylinder of an internal combustion engine with the use of a suitable pressure sensor and to recognise certain operational states of the engine from the pressure course in dependence on crankshaft angle, from which control signals for the control of the engine can be obtained. Usually, a combustion chamber pressure sensor is associated with each cylinder of the engine, and a crankshaft angle sensor is used which supplies an output signal representative of the crankshaft angular setting. The two signals are evaluated by a control system of the engine. Such a device and associated method for the evaluation of the output signals of combustion chamber pressure sensors is known in conjunction with ignition regulation, for example from DE OS 43 41 796. In this known device and method, the point of combustion in each cylinder of the engine is ascertained from the combustion chamber pressure in dependence on crankshaft angle, wherein the measured combustion chamber pressure course is compared with an imaged pressure course. This imaged pressure course is obtained in that the pressure course measured between 0° crankshaft angle and top dead centre (TDC) is continued symmetrically between TDC and 360°. Such a pressure course would arise if the conditions in the cylinder were completely symmetrical and no combustion would take place.

Consideration of the imaged pressure course can lead to inaccuracies under real conditions and there is therefore a need for a possibility of comparing the measured combustion chamber pressure course with a consistently reproducible pressure course in order, from this comparison, to recognise the start of injection, thus the beginning of the injection into the cylinder, or to ascertain the exact position of combustion.

According to the present invention a method of and determining means for determining the beginning of injection or the position of combustion in an internal combustion engine employ at least one cylinder pressure sensor which produces an output signal proportional to pressure, a crankshaft angle sensor which delivers a signal representative of the crankshaft setting, and evaluating equipment which places the output signal proportional to

pressure into relation with the crankshaft angle, characterised in that the measured pressure course in a presettable crankshaft angle interval is compared with at least one pressure course which is computed subject to consideration of thermodynamic relationships and stored in the evaluating equipment, and the beginning of injection or the position of combustion is recognised from the comparison result when the comparison result reaches a presettable threshold value.

Such a method and determining means may have the advantage that a particularly secure and reliable signal evaluation is possible. Due to the accurate possibility of evaluation, the start of injection and the position of combustion can be determined accurately, whereby control signals for regulation of the engine can be formed in equally accurate manner.

Preferably, a cylinder pressure sensor is arranged in each cylinder of the engine and the output signals are fed by way of a multiplexer to a microprocessor of the evaluating equipment, wherein the evaluating equipment is part of a control system of the engine. The engine itself can be a diesel engine, in which fuel is injected directly into the cylinder.

For preference, the computed and stored pressure course is ascertained subject to consideration of a polytropic change in state.

Expediently, the difference between the measured pressure course and the computed pressure course is added up or integrated up over a presettable region and the sum or the integral is compared with a presettable threshold value, the beginning of injection being recognised on reaching of the threshold value. Alternatively, the difference between the measured pressure course and the computed pressure course can be integrated up until the integral reaches a presettable threshold value, the beginning of injection then being recognised on reaching of the threshold value.

Advantageously, the ascertained beginning of injection and/or the ascertained position of combustion is or are taken into consideration for the regulation of the engine and serves or serve each time as actual value for the regulation. A position of combustion can be regulated towards, in which case the centre of concentration of combustion is used as actual magnitude and as setting magnitude of the instant of injection. Preferably, the position of combustion is ascertained by integrating up all differences in a presettable

crankshaft angle interval and the position of 50% of the integral value is chosen as centre of concentration of combustion.

For preference, the signal detection is reset to zero after the beginning of injection has been recognised.

An improved security against interference is obtained by integrating-up the difference values and comparison of the obtained integral with another predetermined threshold value, since short interference pulses are attenuated in their effect by the integration. A condition, which can be defined as a zero point, can be derived from the recognised position of the beginning of injection.

The method and determining means can be used in advantageous manner for a diesel engine. Advantageously, the beginning of injection in that case is no longer regulated towards a target position of the beginning of injection, but towards position of the combustion. The position of combustion can then be obtained by integrating-up all differences of both the pressure courses in a certain interval or over the entire combustion cycle. A point of concentration, or centre of mass of combustion, can be fixed at, for example, a 50% integral and this point then utilised as the actual value of the position of combustion as well as a setting value for the instant of injection.

An example of the method and embodiment of the determining means will now be more particularly described with reference to the accompanying drawing, in which:

Fig. 1 is a block circuit diagram of determining means embodying the invention; and

Fig. 2 is a diagram showing measured combustion chamber pressure courses over an engine crankshaft angular range and computed pressure course over the same range.

Referring now to the drawings there is shown in Fig. 1 determining means for determining the beginning of injection or position of combustion in an internal combustion engine by evaluation of combustion chamber pressure. Individual pressure sensors 14, 15, 16 and 17, which deliver pressure-proportional output voltages U1, U2, U3 and U4, are arranged in the combustion chambers of cylinders 10, 11, 12 and 13 of the engine. Also present is

a crankshaft angle sensor 18 which delivers an output signal S1 indicative of engine crankshaft angle α.

The output voltages of the pressure sensors 14, 15, 16 and 17 and the output signal of the angle sensor 18 are fed to a control device 19, which processes these signals, of the engine. Further signals, for example temperature T, load L, etc., can be fed to the control device 19 by way of inputs 20 and also be processed in the device.

The control device 19 comprises a multiplexer 21, by way of which the output voltages of the pressure sensors can be fed selectively to an analog-to-digital converter 22. The switching-over of the multiplexer 21 takes place in dependence on crankshaft angle and is triggered by appropriate drive control actions of the control device 19. If a multichannel analog-to-digital converter is used, the multiplexer 21 can be dispensed with. Evaluation of the signals takes place in a microprocessor 23 of the control device 19, which delivers control signals S2 and S3 in dependence on the ascertained magnitudes by way of an output unit 23a to different components of the X engine, for example injection signals to an injection system.

The actual signal processing, by way of which the beginning of injection or the position of combustion is ascertained, takes place in the microprocessor 23. For this purpose, the pressure-proportional voltage signal, for example U1, is initially synchronised with the crank angle α. Thereafter, pressure values, for example P1 (α), related to crank angle are available to the microprocessor 23, from which pressure values the beginning of injection is computed and made available as an actual magnitude for regulation of beginning of injection, for example in a diesel engine. The other signal voltages U2, U3 or U4 are evaluated in like manner. In a simple version, it may be sufficient to provide a cylinder pressure sensor at only one cylinder and to evaluate its output signals.

Apart from the measured pressure courses, pressure courses which have been computed or even measured by the combustion chamber pressure sensor during, for example, engine overrun operation, and which have been filed in storage devices are made available to the control device. The pressure courses measured during overrun operation correspond with polytropic pressure courses. It is then advantageous, to take properties specific to the engine or cylinder into consideration. These combustion chamber pressure courses are, in particular, polytropic combustion chamber pressure courses, thus courses

which are computed specific to cylinders by reference to thermodynamic considerations, wherein the computations can be performed, for example, once before first starting the engine or can be updated by new computations under presettable conditions. By comparison of the measured combustion chamber pressure courses with the polytropic combustion chamber pressure courses filed in the storage devices of the control device 19, the microprocessor 23 can ascertain the differences between an actual combustion chamber pressure course and a filed polytropic combustion chamber pressure course, wherein the evaluation shall take place over a presettable crankshaft angle interval of, for example, -180° to 180° crankshaft angle (KW). The difference formation can be carried out in a fixed measurement raster; for example, a difference is formed after each degree of crankshaft angle or differences are formed in a fixed time raster. If a difference thus formed exceeds a presettable threshold value, it is presupposed that the energy conversion and thereby the combustion has just started. The associated crankshaft angle at which the difference exceeds the threshold value for the first time represents the actual position of the beginning of injection. After the recognition of the beginning of injection, the signal detection can be set back to zero.

In a development, the differences between the measured combustion chamber pressure course and a filed polytropic combustion chamber pressure course are integrated up over presettable crankshaft angle ranges. The thus-obtained integral values are compared with a further threshold value and the beginning of injection is then recognised on reaching of the threshold value. This ensures that electrical or mechanical disturbances of the signals do not lead to erroneous recognition of beginning of injection. This can also be made certain by a development, in which the difference values between the measured and the computed pressure course are integrated until the arisen integral value reaches a presettable threshold value. When this threshold value is reached, beginning of injection is recognised. The thus obtained actual position of the beginning of injection, however, lies later than the true beginning of injection, since the integration extends over a certain crankshaft angle or a corresponding time interval. On application of this method, the target position of reaching of the integral value must also be ascertained. The relationship between the start of injection (SB) ascertained from the difference and that ascertained from the integral is evident from Fig. 2. In the first case, the ascertained beginning of injection lies at αSB. The integral I however ends only at TDC. If the combustion chamber pressure course is known, the actual beginning of injection can be computed from the crankshaft angle at which the integral value reaches the threshold value.

The combustion chamber pressure is entered as a function of crankshaft angle α in Fig. 2, wherein the upper curve A represents an actual combustion chamber pressure course during engine operation with drive by combustion, whilst the lower curve B shows a combustion chamber pressure course computed by reference to thermodynamic considerations subject to consideration of the polytropic relationship, and filed in the control device.

For regulation of the engine, for example a diesel engine, the ascertained crankshaft angle for the beginning of injection αSB can serve as an actual value. Regulation to the target value then takes place in usual manner subject to consideration of the actual value. In a modification of this regulation strategy, regulation is carried out not to the target position of the beginning of injection, but to a position of the combustion itself. A restricted beginning of injection does not influence emission of noxious exhaust substances or fuel consumption of the engine, but the true position of the combustion. For that reason, the position of combustion can be ascertained instead of the beginning of injection. To obtain the position of combustion, all difference values between the measured pressure course and the computed and filed pressure course are integrated up, wherein this integration can take place in a certain interval or over the entire combustion cycle between -360° and +30° crankshaft angle. From this integral, the point of concentration of combustion can be ascertained, which lies at, for example, 50% of the integral value. This point of concentration of combustion can then be utilised for regulation as actual magnitude of position of combustion. The setting magnitude is in that case again the injection time.

The described example and embodiment can be used generally for internal combustion engines, particularly for diesel engines in which diesel fuel is injected directly into the cylinders, or petrol engines with direct injection of petrol. In the case of conventional petrol engines, in which fuel is injected into the induction duct ahead of the respective cylinder, the method can be applied for evaluation of the course of combustion. For example, the position of combustion can be ascertained.

CLAIMS

1. A method of determining the start of fuel injection or point of combustion in an internal combustion engine, comprising the steps of computing a course of combustion chamber pressure in a cylinder of the engine over a predetermined range of angular setting of the engine crankshaft with consideration of thermodynamic relationships, storing the computed pressure course, measuring combustion chamber pressure in that cylinder and crankshaft angular setting, correlating measured values of the pressure and setting to obtain a measured pressure course over the predetermined range, reading out the computed pressure course, comparing the computed and measured pressure courses, and recognising start of injection or point of combustion when the difference between the compared courses reaches a predetermined threshold value.

2. A method as claimed in claim 1, wherein said steps are carried out for each of a plurality of cylinders of the engine and the step of measuring comprises measuring the combustion chamber pressures by individual pressure sensors each providing an output signal indicative of the measured pressure for a respective cylinder, and supplying the output signals by way of multiplexing means to evaluating means.

3. A method as claimed in claim 1 or 2, wherein the engine is a diesel engine with direct injection.

4. A method as claimed in any one of the preceding claims, wherein the step of computing is carried out with consideration of polytropic change in state.

5. A method as claimed in any one of the preceding claims, wherein the step of recognising comprises summating or integrating the difference between the compared courses over a predetermined region and comparing the obtained sum or integral with a predetermined threshold value.

6. A method as claimed in any one of claims 1 to 4, wherein the step of recognising comprises integrating the difference between the compared courses until the integral reaches a predetermined threshold value.

7. A method as claimed in any one of the preceding claims, comprising the further step of utilising the recognised start of injection or point of combustion as an actual value in regulation of operation of the engine.

8. A method as claimed in any one of claims 1 to 6, comprising the further steps of determining the point of concentration of combustion and utilising the determined point of concentration as the actual value of point of combustion and as a setting value for instant of injection in regulation of engine operation by reference to point of combustion.

9. A method as claimed in claim 8, wherein the step of determining the point of concentration comprises integrating the difference between the compared courses over a predetermined crankshaft angle range and selecting the point at which the integral value is at 50 percent as the point of concentration.

10. A method as claimed in any one of the preceding claims, wherein the steps of measuring, correlating, reading-out, comparing and recognising are repeated after each recognition of start of injection or point of combustion.

11. A method as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

12. Determining means for determining the start of fuel injection or point of combustion in an internal combustion engine, comprising means for computing a course of combustion chamber pressure in a cylinder of the engine over a predetermined range of angular setting of the engine crankshaft with consideration of thermodynamic relationships, storing the computed pressure course, measuring combustion chamber pressure in that cylinder and crankshaft angular setting, correlating measured values of the pressure and setting to obtain a measured pressure course over the predetermined range, reading out the computed pressure course, comparing the computed and measured pressure courses, and recognising start of injection or point of combustion when the difference between the compared courses reaches a predetermined threshold value.

13. Determining means as claimed in claim 12, comprising individual pressure sensors for measuring the combustion chamber pressures of a plurality of cylinders of the engine

and each providing an output signal indicative of the measured pressure for a respective cylinder, and multiplexing means for supplying the output signals to evaluating means arranged to produce, store and read out such a computed pressure course for each of the plurality of cylinders and to compare computed and measured courses for each cylinder and recognise start of injection or point of combustion for that cylinder from the respective compared courses.

14. Determining means as claimed in claim 13, wherein the evaluating means is present in a control system of the engine.

15. Determining means as claimed in any one of claims 12 to 14, wherein the engine is a diesel engine with direct injection.

16. Determining means as claimed in any one of claims 12 to 15, the determining means being arranged to produce the computed pressure course with consideration of polytropic change in state.

17. Determining means as claimed in any one of claims 12 to 16, the determining means being arranged to recognise the start of injection or point of combustion by summating or integrating the difference between the compared courses over a predetermined region and comparing the obtained sum or integral with a predetermined threshold value.

18. Determining means as claimed in any one of claims 12 to 16, the determining means being arranged to recognise the start of injection or point of combustion by integrating the difference between the compared courses until the integral reaches a predetermined threshold value.

19. Determining means as claimed in any one of claims 12 to 18, further comprising means for utilising the recognised start of injection or point of combustion as an actual value in regulation of operation of the engine.

20. Determining means as claimed in any one of claims 12 to 18, further comprising means for determining the point of concentration of combustion and utilising the determined point of concentration as the actual value of point of combustion and as a

setting value for instant of injection in regulation of engine operation by reference to point of combustion.

21. Determining means as claimed in claim 20, the determining means being arranged to recognise the point of concentration by integrating the difference between the compared sources over a predetermined crankshaft angle range and selecting the point at which the integral value is at 50 percent as the point of concentration.

22. Determining means as claimed in any one of claims 12 to 21, the determining means being arranged to repeat the actions of measuring, correlating, reading-out, comparing and recognising after each recognition of start of injection or point of combustion.

23. Determining means substantially as hereinbefore described with reference to the accompanying drawings.

24. An internal combustion engine provided with a system for controlling operation thereof, the system comprising determining means as claimed in any one of claims 12 to 23.

The Patent Office

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Application No: GB 9823890.0
Claims searched: 1-24

Examiner: Steven Davies
Date of search: 25 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1N-NAAJCR

Int Cl (Ed.6): F02B-77/08 ; F02D-41/34, 41/38, 41/40

Other: Online databases: WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2255831 A	(ROBERT BOSCH)	
A	US 5611311	(NAOKI)	
A	US 4995351	(SATORU et al)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		